APPENDIX A

FUEL CELL TECHNICAL ADVISORY PANEL

Automotive Fuel Cell Technology Information Questionnaire

I. Fuels for Fuel Cells

Please identify the fuel(s) your organization has selected as the most appropriate choice(s) for automotive fuel cells in the near term (5-8 years) and over the longer term (>10 years), and provide answers to the following questions if possible:

1. What are the major reasons for selecting the fuel(s)? What will be the main advantages and disadvantages of this/these fuel(s) in the nearer and longer term? (Please address technical, economic and environmental factors.)

2. Will the fuel processor have multi-fuel capability? For which fuels?

3. Will the fuel(s) have to meet stringent purity or other restrictive specifications to be suitable for your program's fuel cells?

4. What are your current views regarding the characteristics of the fuel supply (production, storage, distribution) infrastructures and/or industries that will be needed to make the fuel(s) generally available? What are your assumptions regarding the impact of these infrastructures on fuel cost at different scales? Are potential environmental, safety, and/or health issues likely to arise, and how might they be addressed?

5. In which physical state will the fuel(s) be stored on the vehicle? What type of vehicle fueling interface with the fuel supply infrastructure is likely to be used, and which safety issues will need to be resolved as a consequence of fuel transfer and storage?

6. What are your assumptions regarding availability and cost of the fuel(s) you selected (compared to current motor fuels) for the nearer and longer term? What are the main bases of your assumptions?

II. Fuel Cell Power Plant

If your program is developing, testing, and/or demonstrating complete automotive fuel cell power plants, please answer the following questions as completely as possible:

1. What are the main functional components and subsystems of your organization's fuel cell power plant technology?

2. Which level of development (e.g., laboratory device; breadboard; engineering prototype; production prototype; commercial product) have you and/or your suppliers attained for each of the major subsystems? What is the current development status of the complete power plant, and what is the timetable for completion of power plant development?

3. What are the current operating, performance and life characteristics (please include your definition of end-of-life!) of the fuel cell power plant:

    a) Voltage; capacity (kW continuous & peak); weight; volume

    b) efficiency at maximum and part load c) start-up and restart times and operating characteristics

    c) transient response to load changes

    d) shut-down and storage procedures

    e) voltage degradation with time of operation

    f) endurance/life (hours of operation @ standard conditions)g) main failure mechanisms (subsystems; system)

4. Has your organization operated a stand-alone fuel cell power plant on the test stand? In a vehicle? What were the major lessons?

5. What are the general characteristics of your organization's power plant, including:

    a) Maintenance requirements and maintainability

    b) capability for self diagnostics

    c) off-design operation

    d) fail-safe operation

    e) emission levels

6. Does the power plant have special requirements for operation and/or maintenance (e.g., pressurization, water addition, conditioning of input air, etc.) at its current state of development and/or when fully developed?

7. Which operating, performance and life characteristics have you set as program goals for items 3.a) - f)? On what basis have you set these goals?

8. Will achievement of the power plant performance and life goals require major technical advances/breakthroughs over current component, subsystem and/or system technologies? Which? How do you expect to achieve them? Over which period?

9. What is your organization's fuel cell power plant cost goal (e.g., in $/kW)? On what basis have you set this goal? How does the power plant goal break down in cost goals for the major subsystems and components?

10. Which advancements (in component, subsystem and/or system materials and manufacturing technologies) will be needed to attain your power plant cost goals? How do you plan to achieve these advances? Over what period?

11. Will an energy storage function be necessary to meet the vehicle performance and/or cost targets? Which type of energy storage device is likely to be used, and in which powertrain configuration?

12. What are your plans for manufacturing development and manufacturing of automotive fuel cell power plants?

III. Fuel Management/Processing

Please provide as much information as possible on the fuel, air and water management/processing subsystems required to operate your organization's fuel cell power plant on the fuel(s) selected for it:

1. What system is used, or planned to be used, to process the fuel stored onboard the vehicle into a fuel stream that is compatible with the fuel cell stack?

2. Does (or will) the fuel processing system have multi-fuel capability? For which fuels?

3. What were the main considerations and requirements that led to the selection of the fuel processing approach?

4. What are the specifications (especially in terms of deleterious fuel contaminants or components) for the fuel processor input fuel? For the fuel processor output stream? What special process steps are and/or will be used to achieve these specifications?

5. What type of air management/processing subsystem is used, and how is it (or will it be) integrated into the power plant?

6. How are water storage and recovery maintained over the range of operating conditions of the power plant?

7. What are the currently achieved fuel processor operating, performance and life/endurance characteristics (please provide data), including:

   a) Capacity (kW continuous & peak); weight; volume

   b) operating temperatures and pressure(s) of processor subsystems

   c) fuel utilization (conversion efficiency) under representative operating conditions (full and part load)

   d) processing heat source utilized during various modes of system operation

   e) achievement of required low levels of CO and hydrogen sulfide (where applicable)

   f) dynamic behavior (start-up and transient response)

   g) life-limiting factors (catalysts and other materials)

8. Have packaging and weight (including weight distribution) goals been defined for the fully developed fuel processing system? To which extent have the goals been achieved, and/or do you expect to achieve them with further development?

9. Have the range (in terms of power) and rate of the required fuel processor transient response been defined? On what basis? To which extent have these been achieved, and/or do you expect to achieve transient response goals with further development?

10. What are the major advances or breakthroughs required to achieve the improvements in fuel processor performance and durability characteristics dictated or implied by power plant goals (see II.7., above)? When do expect to have realized these advances?

11. If your current estimate for the cost (e.g., in $/kW) of the fuel processor subsystem produced in commercial quantities exceeds the goal implied by the power plant cost goal (see II.10. above), how will costs be reduced?

12. What are your organization's (or supplier's) plans for manufacturing development and manufacturing of fuel processor technology?

IV. Fuel Cell Stack

Please provide as much information as possible on the fuel cell stack technology on which your organization's fuel cell power plant is based:

1. Current and prospective suppliers of the key functional stack components, or supplier(s) of the stack technology if stacks are not fabricated by your organization?

2. Current and prospective technical and cost characteristics of the key stack components:

   a) Proton Exchange Membrane (PEM):

   - producer(s) and supplier(s)
   - chemical composition (generic)
   - performance characteristics (resistance @ temperature, etc.)
   - degradation rate and mechanism(s) under representative fuel cell stack operating conditions
   - off-spec operating conditions degrading PEMs rapidly
   - current PEM cost (e.g., in $/unit area)
   - costs projected when purchased in commercial quantities (please indicate the quantities)
   - please indicate how further development and/or future mass production will reduce costs to the target level, and which organizations are planning or likely to make the investments in R&D and/or the production plant required to achieve PEM target

   b) Bipolar Plate:

   Please provide the same information as for the PEM (see V.1.)

   c) Catalyst-Membrane assembly:

   - producer(s) and supplier(s)
   - catalyst used (generic); catalyst loading (e.g., in mg/sq.cm)
   - performance characteristic (current density-cell voltage relationship @ catalyst loading and temperature)

- degradation rate (e.g., voltage loss @ constant current) and mechanism(s)
- current cost (e.g., in $/unit area)
- costs projected when purchased in commercial quantities (please indicate quantities)
- please indicate how further development and/or future mass production will reduce costs to the target level, and which organization(s) are planning or likely to make the necessary

3. Stack operating temperature (range), and upper as well as lower temperature limits to avoid damage to the stack and/or its components.

4. Thermal management approach: heating to operating temperature; systems for cooling and for utilization of rejected heat

5. Management of water: humidification; cathode-anode water balance

6. Approach/systems for conditioning of input fuel and air (control of CO, moisture, etc.)

7. Currently achieved performance and life/endurance characteristics including:

   a) CO, hydrogen sulfide and/or other impurity concentrations in the processed-fuel input stream which can be tolerated by the stack in steady-state and under transient conditions

   b) cell-level current density-voltage characteristic

   c) thermal efficiency at full and part load

   d) stack net power, total weight and volume

   e) response time to load transients

   f) voltage degradation rate under operating conditions

   g) stack life (hours of operation between replacements)

   h) main stack failure mechanism(s)

8. Performance and life/endurance goals for 7. a) - g), above, for the fully developed stack technology?

9. If current performance and life/endurance fall short of goals, please indicate how the goals will be attained. Are major advances or technical

breakthroughs required? Which? Are your organization and/or suppliers currently pursuing the necessary advances?

10. Please indicate the state of development of stack hardware. Are there currently unresolved technical and/or prospective cost issues associated with stack hardware? Which, and how do you plan to resolve these issues?

11. What is your organization's current estimate of the cost of the complete fuel cell stack if produced in commercial quantities? (Please indicate what you would consider commercial quantities.) If the estimate exceeds the goal implied by the power plant cost goal (see II. 9., above), how will costs be reduced?

12. What are your organization's and/or your suppliers' plans for manufacturing development and manufacturing of fuel cell stack technology?

V. Auxiliary and Control Subsystems

Please provide as much information as possible (including technical specifications) on the most important ancillary and control subsystems and components that are, or will be, required to support and control the operation of your organization's fuel cell power plant, including:

1. Fuel storage & delivery

2. Pump(s) and compressor(s)

3. Heat exchangers

4. Control philosophy and required controllers

5. Instrumentation

Please indicate whether subsystems and components (above) meeting technical and cost specifications are already available to your program, or whether development and/or engineering is required. If the latter, are organizations committed or likely to carry out these developments and make the subsystems/components commercially available?

Also, please indicate whether other major subsystems -- such as regenerative braking and the associated battery or other energy storage devices -- will be part of the complete automotive power plant using the fuel cell as the prime mover. How do these subsystems impact the technical and cost specifications of the fuel cell system itself? Is your organization's fuel cell power plant program already engaged in the evaluation and/or development and/or integration of regenerative breaking and energy storage subsystems?

VI. Prospects and Strategies for the Realization of Automotive Fuel Cells

The Panel is soliciting your views and opinions on the outlook for fuel cells in automobile propulsion and the steps that should or could be taken by the various stakeholders in industry (including the automotive industry) and government to determine and realize these prospects:

1. Has technical progress in recent years on key aspects of automotive fuel cell technology created an adequate basis for engineering development of fuel cell power plants that will be able to meet the performance, life and cost requirements for automotive applications? If not, in which aspects of the technology are major advances or breakthroughs required to establish that basis?

2. Are current national and/or international resources and activities sufficient to result in the required engineering developments? Are they sufficient to pursue major advances or breakthroughs if required? How do you judge the probability that such advances will be achieved in the nearer or in the longer term if the required resources are made available?

3. Are current national and/or international institutional arrangements and/or incentives adequate for commercialization of successful automotive fuel cell power plant technology developments? If not, what kinds of arrangements and incentives would you advocate?

4. Assuming for the moment that adequate resources and incentives will be/become available, how do you judge the prospects of fuel cells for automotive propulsion of personal automobiles? Of commercial vehicles?

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